ICHEP 2022 Newsletter - Day 1 (07/07/2022) Highlights from Parallel Sessions

Beyond the Standard Model

Day 1 of the Beyond-the-Standard Model (BSM) sessions covered both the state-of-the-art phenomenological ideas, new constraints on a variety of models, and results and projections from past and future experiments that span multiple decades (from Babar to future colliders). The first session had a lot of variety, from new BSM models that could address existing anomalies, to future collider prospects and dark sector searches. There was also an exciting update on the hunt for the X17 boson at MEGII. The X17 boson or "Atomki anomaly" has generated some excitement in the field, and we look forward to future results in this area. Dark photon explanations featured in several talks in the second session, including PADME and NA64. This session had a great coverage of non-LHC experiments targeting dark sector models and milli-charged particles. New theoretical calculations for calculating "portal

effective field theories" were also presented. The first significant excess that showed up at the conference was… the "excess" of presentations related to leptoquarks in the first afternoon session: this indeed testify the renewed interest in the field after the recent hints of flavor violation. However, there was an interesting breadth of topics from TeV scale phenomenology to the possible impact on proton decay. SUSY theoretical developments and experimental searches from ATLAS and CMS have been presented showing no discrepancies and thus setting more stringent limits on parameters of the supersymmetric particles. In a nutshell- the first day of ICHEP demonstrated both the quality and breadth of work going on in the experimental and theoretical community related to BSM physics. There was lively discussion and we look forward to the rest of the conference.

Higgs Physics

The Higgs Physics session is in the light of the 10 years' anniversary of the Higgs boson and the restart of the third data taking period of the LHC with stable beams at a record-breaking proton-proton center-of-mass energy of 13.6 TeV. Speakers from both the ATLAS and CMS collaborations showed new results with unprecedented precision. The inclusive and gluon-fusion-production cross sections in the bosonic final states are now measured to a precision of 10% or better, while the vector-boson-fusion production mode has now been observed with more than 5 standard deviations in several individual channels. Differential cross-section measurements, both using fiducial definitions and production-mode specific categories ("Simplified Template Cross Sections") have been newly performed in several channels by both collaborations, reaching unprecedented precision and comparing with various prediction, as well as performing interpretations in Effective Field Theories and other models.

Both collaborations zoom in on the coupling of the Higgs boson to the charm quark, with an observed precision on the charm coupling modifier κ_c from direct VH, $H \rightarrow cc$ (V = W or Z) measurements $1.1 < |\kappa_c| < 5.5$ at 95% confidence level (CMS), and from a combined measurement of the same channel with VH, $H \rightarrow bb$ and with the measurement of the Higgs boson transverse momentum using the $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4\ell$ (ℓ = e or μ) channels obtaining $-2.47 < \kappa_c < 2.53$ at 95% confidence level (ATLAS).

CP-odd contributions to Higgs-boson interactions with fermions in the Yukawa couplings can in principle happen at leading order. Both ATLAS and CMS presented impressive results probing the top-Higgs and Higgs-tau couplings. ATLAS presented a new VVH CP analysis using the VBF $H \rightarrow \gamma\gamma$ channel.

ATLAS presented a brand new Higgs-boson mass measurement in the $H \rightarrow ZZ^* \rightarrow 4\ell$ channel using the full LHC dataset obtaining 124.94 GeV with a total uncertainty of 180 MeV, of which only 30 MeV is from systematic sources.

Both ATLAS and CMS highlighted their brand new combined Higgs-boson analyses using the full LHC Run-2 dataset. The precision on the total signal strength (i.e. the observed rate over SM-prediction) achieves now a total uncertainty of 6%, the Higgs-boson couplings modifiers are obtained with precisions between about 6% and 25%, and 95% confidence level upper limits on invisible decays of the Higgs boson as good as 13% are measured, where 8% were expected (ATLAS).

Several speakers highlighted special techniques and methods to perform the sophisticated analyses. Amongst these are multivariate analyses that perform a many-dimensional interpolation between different matrix elements or parton showers for systematic control, embedding heavy-flavor jets or taus into $Z \rightarrow \ell\ell$ events, special techniques for highly-boosted jets originating from an $H \rightarrow bb$ or cc event, and other.

New and impressive observed upper limits on the signal strength of double-Higgs production were obtained by ATLAS (observed 2.4 × SM, expected 2.9 × SM) and CMS (observed 3.4 × SM, expected 2.4 × SM), also zooming in on the allowed range of the trilinear Higgs coupling modifier κ_λ with the strongest current result obtained by the ATLAS Collaboration in a combination of single-Higgs and double-Higgs measurements resulting in $-0.4 < \kappa_\lambda < 6.3$, which deteriorates only slightly when letting other coupling modifiers free in the fit and thus being less model dependent. The strongest result on the coupling modifier κ_{2V} for the VVHH quartic interaction, $0.67 < \kappa_{2V} < 1.38$, excluding $\kappa_{2V} = 0$ with 6.6 standard deviations, was obtained by the CMS Collaboration in their HH combination, relying heavily on the boosted VBF HH → bbbb channel.
New interpretations of single-Higgs-boson and double-Higgs-boson results in the Standard Model Effective Field Theory (SMEFT) and Higgs Effective Field Theory were presented by the ATLAS Collaboration, respectively. For the first time, also a combined SMEFT interpretation of Higgs, electroweak, and LEP/SLD precision results was performed (ATLAS). No significant deviations from the Standard Model expectations were observed yet, however impressive advances in the methodology and results were shown.
New projections to 3000 fb-1 integrated luminosity with the High-Luminosity LHC were shown by both the ATLAS and CMS collaborations. The projected uncertainty on the mass of the Higgs boson is up to 30 MeV (CMS) and 33 MeV (ATLAS), while the expected direct upper limit at 95% confidence level on the width is 177 MeV (CMS). The Higgs-muon coupling modifier is expected to be measured with a precision of 3.5% (CMS), while the expected H → ττ cross section uncertainty is 5% (ATLAS), and the expected signal-strength uncertainty of VH, H → cc is 80% (CMS). The HH production is expected to be seen with 3.2 standard deviations over the background-only hypothesis and the 1 standard deviation allowed range for κ_λ is expected to be [0.5, 1.6], based on a combined extrapolation of the HH → bbττ and HH → bbγγ channels (ATLAS).
Prospects for lepton colliders, exploring the possible changed to the branching ratios of h → bb, h → cc, and h → bs were explored in the Minimal Supersymmetric Standard Model, showing where the current LHC results place constraints.
The need for higher-order corrections for calculations of decay modes of additional Higgs bosons was discussed. And several new aspects of Higgs-boson physics beyond the Standard Model were discussed, including implications from the electroweak phase transition, as well as connections to future gravitational wave measurements.

Accelerators

Many new ideas and technical advancements are ongoing in the Accelerators area both for the shorter-term as well as for the longer-term projects being studied/designed for the post-LHC era. In the first day of the Accelerators session at ICHEP 2022, reports included many technical aspects and studies of such projects: from innovative ideas for beam sources, cooling techniques, high-power accelerators for neutrino experiments, to the various options for the future circular colliders being studied for the post-LHC era at CERN (FCC-hh, FCC-he, FCC-ee) or in China (CEPC). Presentations of the status of the linear colliders (ILC and CLIC) and the electron-ion collider (EIC) were also given. A description of the progress towards the CERN Gamma Factory and machine-detector interface studies for the muon collider were also given. A general overview of the physics potential of the various future accelerator options, with focus on their discovery potential, level of maturity and necessary R&D was also given, and will be followed in tomorrow's session by a discussion on the plans for future High Energy

Physics Facilities in the US. The variety and quality of the presentations clearly shows the vitality of the Accelerators community around the world and the high level of expertise that is necessary to ensure the success of both the present and future machines as a crucial ingredient for the High Energy Physics research program.

Heavy Ions

Precise new measurements of heavy-flavor hadrons by the LHC collaborations were reported which will help quantifying the interaction of charm and beauty quarks with the dense QCD medium created in heavy-ion collisions. It was shown that charm and beauty quarks interact with the medium via collisional and radiative processes with a clear quark mass ordering. Heavy flavor quarks also participate in the collective flow and hadronise via recombination in addition to fragmentation. ALICE and STAR collaborations reported precise measurements of scaling of the elliptic flow with the number of valence quarks which provides another important input to understand the hadronization process in the dense QCD environment. Scan of jet size dependence of radiative energy loss of partons in the QCD medium was presented by CMS. While significant in lead-lead collisions, observations of no radiative energy loss in smaller collisional systems (p+p and p+Pb collisions) were reported by ALICE. The strangeness enhancement previously measured in pp collisions was shown to be strongly correlated with the effective energy freed in the collision implying a relation with initial state rather than final state effects. By analyzing beam-gas interactions, LHCb reported an expected detached-to-prompt antiproton production in p+He collisions, largely underestimated by theoretical models and very relevant also for astroparticle physics. Further, the MOeDAL collaboration reported limits on the mass of hypothetical magnetic monopole particles derived from measurements for the first time.

Quark and Lepton Flavour Physics

New results on CP violation in b-hadron decays have been presented in the morning by Belle, Belle-II and LHCb that will further constrain the apex of the Unitary Triangle of the CKM matrix. Charm physics took the lead afterward, with very nice measurements of semileptonic D-meson decays from BES-III, lifetime of charmed hadrons from Belle and new CPV results from LHCb. Theorists tried to tackle the known problems related to non-perturbative QCD affecting predictions in charm physics, and pointed the attention on how different measurements of the Cabibbo's angle may reveal physics beyond the Standard Model. In the last session of the day the topics moved to further lighter quarks, with recent results in the search for rare kaon decays from NA48 and NA62. Latest results from KLOE and KLOE-2 have also been shown. A glance to the future of light-flavour physics has been given with the status report and prospects for the KOTO and PIONEER experiments.

Highlights of the day were:

- Belle II showing full time-dependent CP violation analysis to measure sin2beta and direct CPV in B0→ pi0pi0
- LHCb's measurement of direct CP violation in D→pipi

Technology and Industrial Applications

A diverse set of both commercial and non-HEP utilizations of HEP-born technologies was presented at the afternoon session of the "Technology and Industrial Applications" parallel track. The applications ranged from the generation of cryptographically save random numbers from detector noise, to the development of compact accelerators, muon

tomography applications, to medical imaging techniques that have the potential to improve tumor treatment. The session also included the presentations on the quantum computing and quantum sensing from the Fermilab-led national quantum initiative center SQMS in the US, as well as industry progress on quantum computing (IBM) and power electronics (CAEN), as well as an overview of the ATTRACT project, which targets to foster the collaboration between industry and academic research.

Operation, Performance and Upgrade (Incl. HL-LHC) of Present Detectors

The morning session started with presentations about the upgrades for the ATLAS and LHCB detectors in view of the High Luminosity LHC upgrade. There were detailed presentations about the ambitious projects of ATLAS and CMS about the implementation of novel detectors aiming to measure the timing of particles produced at LHC with precisions of few tens of picoseconds, and about the increased physics potential that such detector will allow the experiment to explore. Another highlight of the session was the presentations related to Calorimeters upgrades. The presentation of the High Granularity calorimeter for CMS was a clear example on how the community is pushing the concept of High Energy Physics calorimeter to its limits. The presentations of the improvements on the electronic of the ATLAS calorimeters (Liquid Argon and TileCal hadron calorimeter) and of the CMS Electromagnetic crystal calorimeter highlighted the challenges that the High Lumi LHC environment poses to the existing LHC detectors. The session was concluded with a presentation on the new improved RPC muon chambers to be installed in CMS in view of the High Lumi LHC.

The afternoon session was dedicated to the upgrades, in view of the High Luminosity LHC, of the trackers of the ATLAS and CMS experiment. In both experiments the tracking detectors are divided into an Inner Detector formed by Pixel detectors which give high resolution space points for the passage of the charged particles produced at the interaction point, allowing the reconstruction of the production vertex, and an outer detector, formed by silicon diodes arranged in thin strips which allow tracking the particles in the experiment magnetic field up to the edge of the calorimeters. Both ATLAS and CMS showed the details of the design of mechanics and readout of the respective detectors and presented the status of prototyping of both detectors sensors and the electronics chips forming the readout electronics chain. The expected performance showed major improvement compared to the present tracking detectors. The CMS outer tracker design (similar number of layers to ATLAS, but arranged in pairs) is determined by the request to provide particle momentum at the first level of the trigger (which is synchronous with the 40 MHz accelerator collision rate) The session highlighted the extensive R&D which has been necessary to develop the new detectors able to cope with the extreme radiation fields and extreme data rates typical of the High Luminosity LHC data taking conditions. Several custom ASICS have been developed by both collaborations (in either 130 or 65nm feature size processes). Worth noting are the common developments for some of the electronic components.

Joint session between Detector for Future facilities and Operation, performance

This session covered the upgrade programs of the Belle II and Alice detector representing two collaborations who have very specific research goals, namely study of Beauty quark physics at the KEK accelerator and Heavy ion physics at the CERN LHC collider.

The Belle II collaboration presented in detail the design and performance of the Silicon vertex detector which has been operating since 2019. They also presented ideas on how to make the

experiment robust and performant even in the presence of high backgrounds, facilitating the SuperKEKB running at high luminosity. They presented in detail the present performance of the Data Acquisition system and the proposal to upgrade to use the PCIe40 board, which has been developed for the LHCb and Alice readout, to cope with the data rate of SuperKEKB.
The Alice collaboration has presented some aspects of the upgrade foreseen for the first run of the High Luminosity LHC Run4: the proposal of the Forward Calorimeter upgrade and the impressive proposal to have a vertex detector made by very thin sensor layers which could be 'wrapped' around the beam pipe. The Alice collaboration concluded the session presenting their (very innovative) ideas about Alice3 (upgrade of the ALICE detector to operate in the last phase of the High Luminosity upgrade of LHC) in order to exploit the full potential of LHC heavy ion program.

Astroparticle Physics and Cosmology
The Astroparticle Physics and Cosmology session parallel session started on Thursday focussing on Early Universe with the latest developments in theory and phenomenology of phase transitions and (p)reheating after inflation. The future measurements of the cosmic microwave background were then discussed, with a focus on cosmological birefringence, a signal of parity violating interactions whose tantalizing latest measurements have drawn a lot of attention. In the following first slot on gravitational waves, we had a review of the latest results from the LIGO-Virgo-Kagra collaboration and perspectives on the next generation of detectors. The first day was closed by an in-depth review of the 10 year results of the AMS collaboration, with an update on statistically significant differences between primary and secondary cosmic rays and a preliminary measurement of the beryllium isotopes fluxes.

Formal Theory
We had a very diverse list of topics ranging from the study of observables in classical and quantum gravity to formal aspects of quantum field theory, model building and phenomenology. In the gravity part: Axel Mass outlined his approach to observables in quantum gravity, and Domenico Bonocore discussed classical gravitational scattering using the worldline formalism, which is an active area of research in the amplitudes community. In the more QFT part: Norma Selomit Ramirez Uribe outlined a quantum algorithm to generate multiloop topologies using loop-tree duality in the context of perturbation theory, Ariel Edery presented some new results on the Nielsen-Olesen vertex coupled to Einstein gravity in the three-dimensional Anti-de Sitter space, and Supratim Das Bakshi spoke about the positivity bounds for the dimension-8 operators in the context of Standard Model Effective Field Theory (SMEFT) and the effects caused by renormalization group flow. In the model building set of talks, Aldo Deandrea discussed new mechanisms for symmetry breaking from negative curvature geometries called nilmanifolds and their application to the compactification of 7D Yang-Mills theory, Haiying Cai spoke about graviton-scalar exchange in the multibrane extension of the Randall-Sundrum model and showed that the radion mass is below the cutoff scale of the IR brane. In the phenomenological part, Roman Pasechnik presented his new approach on a unified description of gauge interactions and flavor structure in the Standard model called the Flavoured Trinification GUT framework, Carlos Tamarit discussed the strong CP problem, fermionic correlators from cluster decomposition and summing over topological sectors, Zhiwei Wang spoke about the dark sector, bubble nucleation and gravitational waves in the context of strongly coupled dark hidden sector, and Pham Ngoc Hoa Vuong discussed axion-gauge bosons couplings, the relation between

anomalous and EFT coefficients in the context of axion EFT. Overall, we had a very smooth day, full of nice talks, interesting questions and pleasant discussions.

Top and EW Physics

The top quark and electroweak session started with the presentation of the state of art measurements on top and W/Z boson productions performed by the LHC experiments (ATLAS, CMS and LHCb). One of the several topics discussed was the precise measurements of the angular distributions of the leptons, derived from the heavy boson decays, and their importance in measuring fundamental quantities of the Standard Model of particle physics (SM). The middle part of the session has been mainly dedicated to the indirect searches for new physics, both in the top decay as well as considering several results at the same time in the effective field theory (EFT) framework. Several EFT studies were reported, investigating the importance of complete calculations and presenting the prospective for future results in measuring rare processes such as Vector Boson Scattering and four top-quarks production. The last part of the day was dedicated to one of current "hot" topics in High Energy Physics, the measurement of the W mass and in particular the tension between the recent CDF result and the SM. The session started with a presentation of the very precise CDF result, followed by a report from the recent LHCb measurement. The following presentations analyzed in detail the tensions between the CDF mW measurement and the previous experimental ones, trying to investigate the cause of the difference, that could lie in the theoretical assumptions employed in the different measurements. The discussion included also the reports from several global fit groups that investigated the impact of the CDF mW measurement on the best-fit values of other SM parameters and on the search for physics effects beyond the SM. As a final remark, throughout the session there was never a lack of looking to the future, with various reports on the expected precision in measuring electroweak quantities at future colliders.

Strong Interactions and Hadron Physics

The kick-off QCD sessions of ICHEP2022 were extremely lively and full of insightful presentations. A number of topics, ranging from cutting-edge determination of the parton distribution functions of the proton to novel techniques to precisely determine the strong coupling constraint were presented. Theorists and experimentalists put forward new ideas and new measurements to better understand the subnuclear dynamics at high energy colliders, from jets to fragmentation functions, from new insights on well-known processes to fresh analysis of old data that can open new exciting avenues.

Dark Matter

The Dark Matter parallel session track on Thursday focused on the most recent theoretical and experimental developments for collider dark matter searches. The theoretical talks, among other things, highlighted the importance of considering effects such as Sommerfeld enhancement and Bound States for relic density calculations. Improved constraints on dark matter models were presented by the ATLAS and CMS experiments employing novel experimental strategies involving the Higgs boson and the top quark. Strong bounds on the dark sector were also presented by Belle-II experiments, while the LHCb speaker also introduced novel ideas to further extend the sensitivity to long lived particles. The session track ended with outlooks on the future of dark matter searches, ranging from future collider prospects to construction plans for smaller scale fixed-target experiments.